

Sensitivity of the parameters measured in pp collisions on the gluon PDF.

E. Cuautle,^{*} A. Ortiz,[†] and G. Paic[‡]

*Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México
Apartado Postal 70-543, México Distrito Federal 04510, México.*

(Dated: January 5, 2010)

The sphericity distribution in minimum bias events obtained with PYTHIA event generator, incorporating different parton distribution functions is presented. The results show that for minimum bias pp collisions the sphericity distribution for different parameters like the mean transverse momentum and multiplicity exhibit strong sensitivity on the parton distribution function used. The results indicate that early data at the LHC could be used in this type of analysis to fix the gluon distribution function in the proton.

PACS numbers: 24.85.+p, 12.38.-t

I. INTRODUCTION

The calculation of the production cross sections at hadron colliders relies upon a knowledge of the distribution of the momentum fraction x of the partons (quarks and gluons) in a proton in the relevant kinematic range, and the corresponding fragmentation functions. Most probably, at LHC, we will be confronted with a copious production of jets what will severely limit the exclusive analysis of individual jets. It seems therefore interesting to separate the events in function of their *multi-jetiness* and to study the parameters of the collisions *e.g.* mean p_t , mean multiplicity, etc., in function of different parton distribution functions (PDF's) present on the market, which as quoted by the CTEQ group allows for an uncertainty of about 10-20% [1]. Obviously this uncertainty will reflect in the quantification of the kinematical processes. The PDF's are of importance to analyze standard model processes at LHC energies [2], and the usual leading order event generators use the PDF's as an input to evaluate hard subprocess matrix elements. In those calculations the multiple parton interactions that make up the bulk of the underlying event, require extensive tuning which depends strongly on the details of the input parton distributions.

The Event Shape Analysis (ESA) has been applied successfully to the restricted acceptance experiments at RHIC and ALICE to survey the possibilities of the method to analyze and isolate specific jet topology events [3]. In the present paper we are investigating the bulk properties of the event shape variables obtained in minimum bias pp events: the sensitivity obtained at different collision energies focussing to minimum bias collisions, corresponding to the minimum x -Bjorken (x_B) achievable. The article is organized as follows: in the section II we give the relation for the sphericity and re-

coil distributions; in the section III we discuss the parton distribution functions used and the way the simulations were done in the framework of minimum bias PYTHIA. The results are presented in section IV and finally, in section V the conclusion are drawn.

II. EVENT SHAPE VARIABLES

Event shape variables allow us to measure geometrical properties of QCD final state [4]. Those variables have been used to analyze dijet production in hadron-hadron collisions and to study the sensitivity of physical parameters [4]. The shape variables at hadron colliders are defined over particles within the acceptance of the detector. The thrust (T) is defined in the transverse plane as follows:

$$T \equiv \underbrace{\max_{\vec{n}_t}}_{\vec{n}_t} \frac{\sum_i |\vec{p}_{t,i} \cdot \vec{n}_t|}{\sum_i |\vec{p}_{t,i}|} \quad (1)$$

where the sum runs over all particles in the final state within the acceptance, $\vec{p}_{t,i}$ represent the transverse component of the momenta of emitted particles and \vec{n}_t is the transverse vector that maximizes the ratio. In the literature it is more common to find the quantity $1 - T$ related to the transverse sphericity of the event. In the present work we do reference to this as sphericity. The range of sphericity is between 0 (for events with narrow back-to-back jets) and $1 - 2/\pi$ (for events with a uniform momentum distribution).

Another interesting observable is the recoil, defined as:

$$R \equiv \frac{1}{\sum_i |\vec{p}_{t,i}|} \left| \sum_i \vec{p}_{ti} \right|. \quad (2)$$

It is an indirect measurement for the radiation which remains undetected for acceptance effects (high imbalance: $R \rightarrow 1$, small imbalance: $R \rightarrow 0$).

^{*}Electronic address: ecuaule@nucleares.unam.mx

[†]Electronic address: antonio.ortiz@nucleares.unam.mx

[‡]Electronic address: guypaic@nucleares.unam.mx

TABLE I: The x_B values for low p_t production at different energies. The evaluation was done at central rapidity, assuming $p_t = 500$ MeV/c.

| \sqrt{s} | x_B | Collider |
|------------|-------------------------|--------------|
| 200 GeV | $\sim 5 \times 10^{-3}$ | RHIC |
| 900 GeV | $\sim 10^{-3}$ | TEVATRON/LHC |
| 10 TeV | $\sim 10^{-4}$ | LHC |

III. THE PARTON DISTRIBUTION FUNCTIONS

The QCD factorization theorem provides us with a framework where distinct parameters can be independently studied in order to interpret the experimental results. Prominent among them we find the parton distribution functions which correspond to the momentum distributions of partons inside a proton. The extraction of the parton distribution function from experimental data and theoretical approach is a complicated task [1, 5]. The uncertainties grow with diminishing x_B and are generally very much larger for gluons than for quarks. At the LHC (Large Hadron Collider) energies, the gluons will play an important role to understand the new physics. Some QCD analysis of parton distribution has been done [1]. At this energies, one will be able to explore regions of small x_B as shown in Table I for minimum bias events.

IV. RESULTS ON EVENT SHAPE VARIABLES AND PDF OF GLUONS

In order to describe the recoil and sphericity variables and their behavior as function of the parton distribution function of the gluon used, we generated a sample of PYTHIA 6.214 minimum bias events [6]. The generation incorporates some parameters proposed as *ATLAS tune*, based on reference [7]. This tuning parameters were fixed to describe the experimental minimum bias data of UA5 and CDF experiments. The pseudorapidity and transverse momenta distribution were the first variables fitted in this tuning. Setting from these fits after that, prediction of the properties of minimum bias and underlying event at LHC energy were scaled.

We have used this version of PYTHIA to implant two different parton distribution functions: ZEUS2005 [8] and CTEQ5L [9]. The latter PDF was extracted from a global analysis to several experimental data while the former is extracted only from HERA data. Plotting the ratio of the two gluon distribution as we have done in Fig. 1, we see that at different energies and Q values they differ substantially, the lowest values of x showing the largest difference.

In Fig. 2 we show in the top panel the mean multiplicity variation with the sphericity variable obtained at central pseudorapidity. We observe an interesting dependence on the PDF used: the mean multiplicity at high

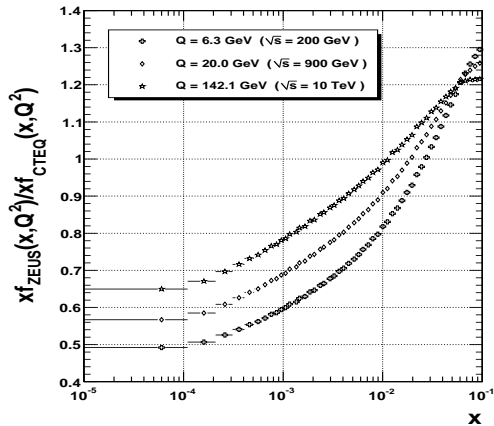


FIG. 1: Ratio of the gluon contributions for the ZEUS and CTEQ5L parton distribution functions, the ratio is shown for different Q values corresponding to the mean Q values obtained from the simulations at 0.2, 0.9 and 10 TeV, respectively

sphericities is much higher for the CTEQ5L PDF than for the ZEUS one. The phenomenon is the most accentuated in the case of the 10 TeV collisions where the x_B value reached is also the smallest. The bottom part of Fig. 2 illustrates this fact, it shows the behavior of the ratio of the mean multiplicities for the three cases as a function of sphericity.

The studies displayed here are within the reach of all the LHC experiments, though we have done the simulation for the case of a relatively small acceptance detector which has the capability to detect low charged particle momenta. We consider only primary tracks within $|\eta| \leq 0.9$ and $p_t \geq 0.5$ GeV/c defined according to reference [10]. In this context they are the particles produced in the collision, including products of strong and electromagnetic decays, but excluding feed-down products from strange weak decays and particles produced in secondary interactions.

In Fig. 3 we show the ratio of the sphericity distributions obtained for the three energies. One observes that in all cases the difference between the two PDF's increases with growing sphericity but much more so in the case of the 10 TeV simulations. This is due to the smaller x_B in that case, where the differences between the two PDF's are the largest. The strong slope in case of 10 TeV data demonstrate the sensitivity of the approach.

Next, the recoil variable is computed according to Eq. 2, the results are shown in Fig. 5 where a characteristic behavior of the ratio of the mean R values is observed for the 3 energies. Namely, The ZEUS PDF has a larger momentum imbalance than CTEQ5L. We explain the feature by the fact that, due to the smaller rise of the gluon PDF in ZEUS one is confronted with an emission of particles resulting from collisions of partons of different momenta, while in the case of the more peaky gluon

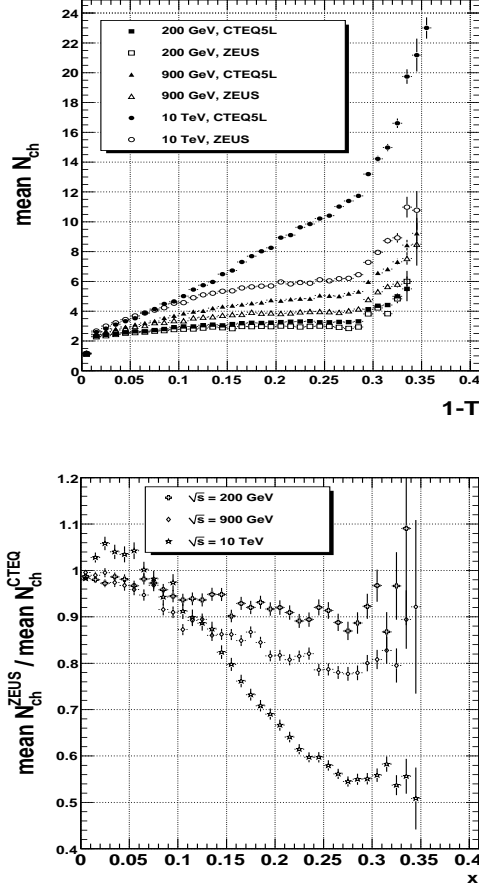


FIG. 2: top: Mean multiplicity in the pseudo rapidity range ± 0.9 obtained at the three energies and the two PDFs in function of the sphericity variable. Bottom: ratio of the mean multiplicities for the two PDF's used for the three energies, again in function of the sphericity variable.

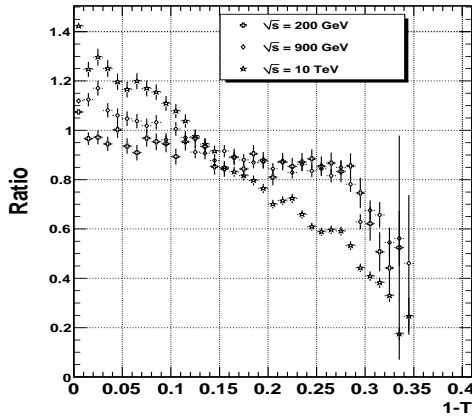


FIG. 3: Ratio of sphericity distributions at different energies

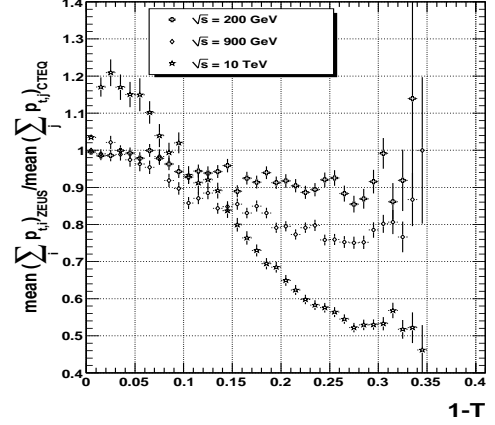


FIG. 4: Ratio of mean total transverse momenta for the two PDFs versus sphericity calculated for 3 energies

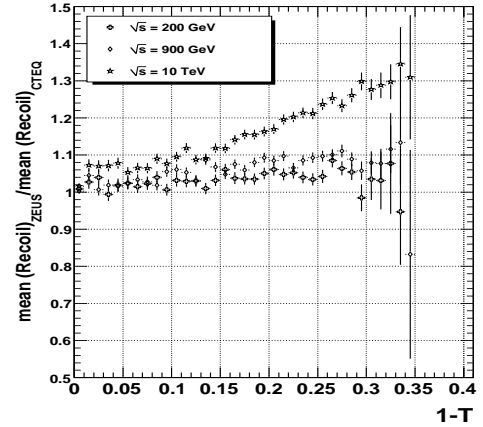


FIG. 5: Ratio of the mean recoil values for two PDF's versus sphericity calculated for 3 energies.

distribution of CTEQ5L the chance of getting a collision of two partons of similar momentum is more probable, hence resulting in a larger probability that the resulting jets be contained within the acceptance.

V. CONCLUSION

The bulk sphericity distributions of several parameters exhibit marked dependence on the gluon PDF used for the computation. As the PDFs for low x_B have a larger uncertainty we believe that the present results point to a possibility to further refine gluon PDFs at low x_B using the approach presented. In the course of this work we have also tried to check the dependence of the parameters on different fragmentation functions used. The results however do not demonstrate a similar dependence as for the PDFs. As one can expect, varying the fragmentation functions one affects slightly the absolute

value of the parameter dependence on sphericity but not the shape.

In summary, the sphericity distributions of several parameters are found to be highly sensitive on the details of the gluon PDF. This opens an interesting possibility to compare the existing gluon PDFs with the experimental results using a small sample of minimum bias data in pp collisions. The Pb Pb collisions, we are currently studying [11] in the same framework will benefit very

much from the present analysis to determine the expected gluon saturation at low x_B .

Acknowledgments

Support for this work has been received in part by DGAPA-UNAM under PAPIIT grants IN115808 and IN116508 as well as by the HELEN program.

-
- [1] Pavel, M. Nodolsky, et. al., *Phys. Rev. D* **78**,013004 (2008).
 - [2] H-L. Lai, et. al., Parton Distribution for Event Generators arXiv:0910.4183
 - [3] A. Ayala et. al., *Eur.Phys.J.C***62** 535, (2009). A. Ortiz, G. Paic, ALICE-INT-2009-015 (hep-ex/0912.0909).
 - [4] A. Banfi et. al., *JHEP* 0408, 062 (2004).
 - [5] W. K. Tung *Perturbative QCD and the parton structure of the nucleon* In *Shifman, M. (ed.): *At the frontier of particle physics, Vol. 2*, 887-971 (2001).
 - [6] T. Sjöstrand, M. Bengtsson, *Comput. Phys. Commun.* 43 (1987) 367.
 - [7] A. Morales, et. al., *Eur.Phys.J.C*, 50:435-466, (2007).
 - [8] (ZEUS Collaboration), *Eur.Phys.J.C*, 42-1:1-16, (2005).
 - [9] H. L. Lai et. al., *Eur.Phys.J.C*, 12-3:375-392, (2000).
 - [10] J. F. Grosse-Oetringhaus and C. Ekman, ALICE-INT-2007-005.
 - [11] E. Cuautle, A. Ortiz, G. Paic, work in progress